First Forging of Gamma Titanium Aluminide Alloy into One-Piece Part Achieved

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Payoff

The new process design method will improve forging designs used to manufacture parts, such as the finished automotive engine exhaust valve shown above, from gamma titanium aluminide alloys and other difficult-to-form materials. Application using isothermal forging to produce near-net shape effectively demonstrates its potential as an improved process design methodology. By using optimization techniques, the new design method also significantly reduces lead time before production, improves part quality and extends the life of the tooling system.

Accomplishment

Scientists at the Materials and Manufacturing Directorate (ML) and Air Vehicles Directorate (VA), jointly developed an advanced computerized method (an advanced process design method using multivariable optimization) that improves the metal forging processes for shaping one-piece aircraft and automobile engine parts using hard-to-form materials. Application of this new design method led to the first known successful isothermal forging prototype automotive engine exhaust valve, using a gamma titanium aluminide alloy.

Background

Gamma titanium aluminide alloys are a family of intermetallic compounds that provide high strength at elevated temperatures with about 40 percent less weight than steel or nickel alloys. Although their high temperature strength makes these alloys promising candidates for future military systems, it also makes them very difficult to form into useful component shapes without fracture. Previous attempts at forging these alloys into near-net shape or one-piece parts have not been fully successful. The requirements for designing the preform stage of the prototype engine exhaust valve forging process included (1) limiting the maximum tensile stress of the workpiece to 25 percent of the flow stress to avoid brittle fracture, (2) limiting the maximum die stress to 340 megapascals (unit of pressure equivalent to one newton per square meter) to avoid tooling damage, (3) limiting the maximum forging temperature to 1473 degrees K due to equipment limitations, and (4) minimizing the process time to achieve a high rate of production. The principle design variables included the shape of the forging die and the forging ram velocity with-respect-to-time profile. The multivariate optimization algorithm was based upon the sequential quadratic programming technique and was used with numerical process simulation to solve the design problem. An optimized design is achieved when a solution satisfies the material and process constraints and minimizes the chosen optimality criterion.